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**NATURAL ENVIRONMENTAL SERVICE SUPPORT TO NASA
VEHICLE, TECHNOLOGY AND SENSOR DEVELOPMENT
PROGRAMS**

Contract Number:

NAS8-36639

Final Report

July 7, 1987, through March 31, 1993

Program Director:

Dr. Michael W. Kalb, Ph.D.

Submitted to:

THE GEORGE C. MARSHALL SPACE FLIGHT CENTER
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April 30, 1993

N93-29029

Unclass

G3/45 0172870

(NASA-CR-192554) NATURAL
ENVIRONMENTAL SERVICE SUPPORT TO
NASA VEHICLE, TECHNOLOGY, AND
SENSOR DEVELOPMENT PROGRAMS Final
Report, 7 Jul. 1987 - 31 Mar. 1993
(USRA) 11 p

QUARTERLY PROGRESS REPORT

NATURAL ENVIRONMENTAL SERVICE SUPPORT TO NASA VEHICLE, TECHNOLOGY AND SENSOR DEVELOPMENT PROGRAMS

NAS8-36639

July 7, 1987 - March 31, 1993

1. Statement of Work

Objective

The research performed under this contract involved definition of the natural environmental parameters affecting the design, development and operation of space and launch vehicles.

USRA provided the manpower and resources to accomplish the following tasks:

1. Defined environmental parameters including thermodynamic and dynamic structures of the atmosphere from the ground to orbital altitudes; the radiation, meteoroid, plasma, and space debris environments; the wind and turbulence characteristics that affect vehicle safety and performance; and, the observational data required for post-flight evaluation of the vehicle performance.
2. Participated in the definition of environmental forecasts required for input to optimize utilization of launch vehicles.
3. Participated in studies to define orbital environments in which space vehicles must operate. These environments included parameters of the neutral atmosphere, the radiation environment, the meteoroid and space debris environments, and geomagnetic and geopotential fields at spacecraft operating altitudes.
4. Worked with users and developers of various environmental models on the proper utilization and interpretation of results derived from the models.
5. Participated in development and study of future technologies and sensors that could contribute to improvement of data and models providing environmental support to both launch and orbiting vehicles. Technologies included satellite-borne and earth based instrumentation, radar wind profilers, space based lidar, McIDAS-type satellite imaging and meteorological analysis systems, as well as satellite borne precipitation monitoring sensors.

Visiting Scientists and Research Associates

Dr. Steve Smith, Ms. Cathy Carlson, Dr. Michael Hickey, Mr. Tim Wilfong, Mr. Robert L. Creasey, Ms. Jeanette Summerville, Mr. Eric R. Corbett, Ms. Lisa Willett, and Ms. Susanna McSwain performed research on this project.

Accomplishments

Dr. Steve Smith performed research in mesospheric atmospheric dynamics during his appointment from April 16, 1986, to April 10, 1989. He also contributed to the

development of the Global Reference Atmosphere Model (GRAM) and helped to establish requirements for a MIDDs computer system to assist with analysis of wind data for shuttle launch support. He also provided support to the Launch Systems Evaluation Advisory Team (LSEAT).

Ms. Cathy Carlson whose appointment was from June 15 - September 18, 1987, worked in the development and implementation of software to investigate the capabilities of Doppler radar wind profiler data for the analysis of mesoscale and synoptic scale systems.

Dr. Michael Hickey performed research on mesospheric gravity waves in support of the GRAM. His work focused on the development of statistical models of natural environments in the upper atmosphere and space. Dr. Hickey's appointment was from May 19, 1986, to July 31, 1990.

Mr. Timothy Wilfong's work focused on integration of MSFC's McIDAS as a node on the MIDDs system. He led the implementation of a Doppler Radar Profiler at KSC and provided expertise in procurement and implementation of a ground based field mill network at KSC for detection of lightning threat. He evaluated and interpreted data derived from these systems and explored techniques for integrating these data into the operational KSC forecast environment.

A new doppler profiler wind retrieval algorithm was developed. Previously, the profiler used 30 minute consensus wind averaging to obtain wind profiles, but this method often gave erroneous winds. An alternative velocity retrieval method was developed by Wilfong and the Advanced Meteorological Unit (AMU) at KSC. It applies a temporal three point median filter to the Doppler Spectrum Data, to provide adjustments to a first guess velocity window. This velocity window can be initialized by Jimsphere data or other wind sources. Once the first guess window has been initialized by a wind profile, the profiler adjusted wind becomes a new first guess profile which is propagated to the next period of time and so on. An article written by Mr. Tim Wilfong, Mr. Bob Creasey, and Dr. Steve Smith entitled, "High Temporal Resolution Velocity Estimates from the NASA 50 MHz Wind Profiler" was submitted to the AIAA Journal of Spacecraft and Rockets which described the process in more detail. Mr. Wilfong worked from July 17, 1989, to October 1, 1991 before being transferred to a project requiring similar expertise.

Ms. Jeanette Summerville ran various atmospheric analyses using the MARS-GRAM computer model, edited several technical documents, and developed a program to analyze the Hydrogen, Oxygen, and Nitrogen mole fraction burned in the Hydrogen Burn test and was able to plot the burn contour lines. Her work began August 15, 1989, and ended December 4, 1990.

Mr. Eric Corbett provided technical support to NASA for work on the analysis of natural environments relative to space and launch vehicles; and specifically the analysis of space debris and statistics of impacts from meteoroids and space debris on spacecraft such as the spacestation. He also participated in the analysis of wind shear data needed for the National Aerospace Plane (NASP) program to help engineers model NASP performance characteristics at various altitudes.

Ms. Lisa Willett assisted with analysis of natural environmental data for a Mars Atmospheric Model and terrestrial environment from December 1, 1990, through March 28, 1991.

Ms. Susanna McSwain supported the development of a natural environment criteria documentation for aerospace vehicle design. She worked from June 10, 1991, through

December 30, 1992. Her work included assessment of program engineering environment requirements, and research, writing and editing of text for the criteria document.

Mr. Robert Creasey began as a Research Associate on August 1, 1991, and continued through contract expiration to support the NASA Vehicle, Technology, and Sensor Development Program. He worked on the 50 MHz Doppler Radar Wind Profiler located at the Kennedy Space Center (KSC), where he examined system noise and sidelobe characteristics, and studied wind persistence statistics with the radar. He was involved in the testing and evaluation of a 915 MHz Wind Profiler System at KSC, proposed to extend the current operating height coverage provided by the 50 MHz Wind Profiling System (WPS).

In addition, Mr. Creasey assisted the Launch Systems Evaluation Advisory Team (LSEAT) by participating in real-time forecasting and evaluation of day-of-launch upper-level winds used for shuttle ascent loads analysis.

In August of 1991, he began analyzing the background noise, affecting the 50 MHz data. One major source, originated from the electromagnetic radiation in the Milky Way Galaxy. The temporal signature of this noise field, that is created as the profiler beams sweep through the galactic plain, displays a predictable double peak every sidereal day. Solar noise was also found to be significant during May and August.

Mr. Creasey and Mr. Wilfong were also involved with the testing and evaluation of the 915 MHz Wind Profiler and Radio Acoustic Sounder System (RASS) at University of Alabama Huntsville, now at KSC. The 915 MHz system is currently collocated with the KSC 50 MHz where the two systems can compute a wind profile from 100 meters to 20 km every three minutes.

Publications and Conferences

Hickey, M. P., "Attenuation Distances of Internal Gravity Waves in the Thermosphere and Their Dependence on the Thermospheric Structure," paper presented at the *Fall Meeting of the American Geophysical Union*, San Francisco, California, December 8-12, 1986.

Smith, S. A., D. C. Fritts and T. E. Vanzandt, 1987, "Evidence for a Saturated Spectrum of Atmospheric Gravity Waves," J. Climate Appl. Meteor., 25, pp. 754-766, 1987.

Hickey, M. P. and K. D. Cole, "A Quartic Dispersion Equation for Internal Gravity Waves in the Thermosphere," J. of Atmos. and Terrestrial Physics, vol. 49, pp 889, 1987.

Hickey, M. P. and K. D. Cole, "A Numerical Model for Gravity Wave Dissipation in the Thermosphere," accepted for publication in the J. of Atmos. and Terrestrial Physics, 1987.

Hickey, M. P., "A Theoretical Comparison of Internal Gravity Wave Propagation and Dissipation in High and Low Temperature Thermospheres: Implications Orbiting Spacecraft," Reprints of the *AIAA 25th Aerospace Sciences Meeting*, January 12-15, 1987, Reno, Nevada.

Hickey, M. P., "Effects of Eddy Viscosity and Thermal Conduction and Coriolis Force in the Dynamics on Gravity Wave Driven Fluctuations in the OH Nightglow," J. Geophysical Research, vol. 93, pp 4077-4088, 1988.

Hickey, M. P., "Wavelength Dependence of Eddy Dissipation and Coriolis Force in the Dynamics of Gravity Wave Driven Fluctuations in the OH Nightglow," J. of Geophysical Research, vol. 93, pp 4089-4101, 1988.

Hickey, M. P., D. L. Johnson, and R. E. Smith, "Comparisons of the MSFC/J70 and CIRA 1986 Thermospheric Models at Suttle (230 km) and Tethered Satellite (130 km) Altitudes: Atomic Oxygen and Total Densities," presented at the *AIAA 26th Aerospace Sciences Meeting*, January 1988, Reno, Nevada.

Hickey, M. P., "An Improvement in the Numerical Integration Procedure Used in the NASA Marshall Engineering Thermosphere Model," Contract Report 179389, August 1988.

Hickey, M. P., "Internal Gravity Waves in the Upper Atmosphere," Invited review paper presented at the World Ionosphere-Thermosphere Study (WITS), Canberra, 1988.

S. Smith, "Cross Spectral Analysis of the Resolution and Precision of Jimsphere and Windsonde Wind Measurements," *Third International Conference of the Aviation Weather System*, Am. Met. Soc., January 1989.

Smith, S., "Progress in the Use of Wind Profiling Radars for Shuttle Launch Support," *Third International Conference on the Aviation Weather System*, Am. Met. Soc., Anaheim, California, February 1989.

Hickey, M. P., "OH Nightglow Fluctuations Due to Internal Gravity Waves," Geophysical Research Letters, July 1989.

Wilfong, T. L., and S. A. Smith, "Satellite Weather PIXS on Your Computer," Computer Shopper, November 1989.

Hickey, M. P., "Gravity Wave Modulations of the Mesopause OH Nightglow," *American Geophysical Union Fall Meeting*, San Francisco, California, December 1989.

Hickey, M. P., "The NASA Marshall Engineering Thermosphere Model," NASA CR-179359.

Hickey, M. P., G. Schubert, and R. L. Walterscheid, "Gravity Wave-Driven Fluctuations in the OH Nightglow From an Extended, Dissipative Emission Region," J. of Geophysical Research, May 1990.

Wilfong, T. L., S. A. Smith, and R. L. Creasey, "High Temporal Resolution Velocity Estimates from the NaSA 50 Mhz Wind Profiler," *AIAA Journal of Spacecrafts and Rockets, Proceedings, AIAA 30th Aerospace Sciences Meeting and Exhibit*, January 609, 1991, Reno, Nevada, 1991.

Wilfong, T. L., S. A. Smith, and C. C. Lapenta, 1991, "NASA's Use of the Ascent Wind Profiler," *Proceedings of the Fifth SCOSTEP/URSI Workshop on Technical and Scientific Aspects of MST RADAR*, August 6-9, 1991, Aberystwyth, Great Britain, 1991.

Nastrom, G. D., W. L. Clark, R. L. Creasey, K. S. Gage, P. M. Pauley, T. E. VanZandt and J. M. Warnock, "Case studies of the Vertical Velocities Seen by the Flatland Radar Compared with Indirectly Computed Values," Journal of Atmospheric and Ocean Technology, 1991.

Wilfong, T. L. and S. A. Smith, "Wind Persistence from 2 - 18 Km Using a Wind Profiler," *31st Aerospace Science Meeting & Exhibit*, Reno, Nevada, January 1993.

Consulting

The following consultants were retained by USRA to perform research on this project. Their activities are listed below in alphabetical order.

Dr. Howie Bluestein, Norman, Oklahoma, participated in a workshop at Johnson Space Center on the relationship of Thunderstorm Forecasting to Shuttle Flight Operations, December 9-10, 1987.

Dr. William Chameides, Georgia Institute of Technology, was appointed to perform a technical review of an updated section of the NASA Technical Memorandum 83473 dealing with Atmospheric Chemistry and Constituents, July 30, 1991.

Dr. C. L. Chandler, Atlanta, Georgia, participated in the NASA workshop at Johnson Space Flight Center on the Relationship of Fog Forecasting to Shuttle Flight Operations, January 19, 1988.

Dr. Brian Collins, Urbana, Illinois, was appointed to present a seminar in the Earth Sciences and Applications Division at NASA/MSFC, May 17-18, 1990.

Dr. Larry Coy, Saint Louis University, was appointed to participate in the 1988 Summer Visitor's Program at NASA/Marshall Space Flight Center, July 25, 1988, through August 26, 1988.

Dr. Clayton T. Crowe, University of Washington, was appointed to collaborate on the analysis of and computational approaches to multiphase flows, February 28, 1988.

Dr. Glenn E. Daniels, Huntsville, Alabama, assisted in reviewing and updating the NASA Technical Memorandum 82473, Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, July 5, 1989, through October 31, 1989.

Mr. Timothy Dye, Penn State University, presented a seminar on Interactive Spectral Reconstruction of Doppler Velocities and held scientific discussions with NASA and USRA personnel concerning wind profiler research, June 4, 1990.

Dr. James Gabrielson, Energy Systems Associates, Inc., was retained to survey results and data sets from the MSFC on potential hydrogen accumulation and explosion during space shuttle launch abort, testing of the model-scale of hydrogen flame quenching in a water spray, and to perform data analysis/reduction, and interpretation, of the results, November 1-30, 1987.

Mr. Chris Guillemot, Boulder, Colorado, presented a seminar to USRA and NASA/MSFC personnel on research in the variability of tropical wind fields, May 6, 1991.

Mr. Joseph Isler, Cincinnati, Ohio, presented a seminar on nonlinear airglow response to NASA/MSFC personnel in the Earth Sciences and Applications Division, September 27-28, 1989.

Dr. Keith W. Johnson, Jackson, Mississippi, collaborated with the Earth Science and Applications Division at NASA/MSFC, August 27-28, 1990.

Dr. C. Justus, Georgia Institute of Technology, was appointed to participate in the NASP-GRAM Workshop held November 15, 1990.

Dr. William W. Kellogg, NCAR, presented a seminar under USRA's "Distinguished Visitor/Seminar Series," May 9-12, 1989.

Mr. Donald Kenzakowski, Jr., Notre Dame University, was retained to consult on his laboratory data acquisition systems, and experiments to characterize charged droplet formation under varying pressures, February 8-9, 1988.

Dr. Steve Knowlton, Auburn University, performed analysis of thermal ion data from Dynamics Explorer-1 spacecraft and carried out research in magnetospheric physics at MSFC, June 20, through August 15, 1989.

Dr. Kevin Knupp, Madison, Alabama, participated in the workshop concerning forecasting techniques and accuracy, and Shuttle Flight Operations, December 9-10, 1987.

Dr. Kenneth K. Kuo, Penn State University, participated in the USRA workshop entitled, "Mixing and Demixing Processes in Multiphase Flows in Application to Propulsion Systems," February 25-26, 1988.

Dr. Russ Laher, Los Angeles, California, presented a seminar in the Earth Science and Applications Division at NASA/MSFC, August 22, 1990.

Dr. Garland Lala, SUNY, was retained to attend the workshop on the Relationship of Fog Forecasting to Shuttle Flight Operations held at Johnson Space Center, January 20-21, 1988.

Dr. David Leighton, University of Notre Dame, Indiana, was appointed to present a paper at the NASA workshop entitled, "Mixing and Demixing in Multiphase Flows With Applications to Propulsion Systems," February 26, 1988.

Dr. Paul A. Libby, University of San Diego, La Jolla, California, was retained to participate in the NASA workshop entitled, "Mixing and Demixing in Multiphase Flows With Applications to Propulsion Systems," February 26, 1988.

Dr. David F. McTigue, Sandia National Laboratory, was appointed to participate in the NASA workshop entitled, "Mixing and Demixing in Multiphase Flows With Applications to Propulsion Systems," February 26, 1988.

Ms. Kathy Mills, Huntsville, Alabama, was appointed to provide scientific programming support and library research for the Natural Environment area, September 1988, through March 27, 1989.

Dr. Yu Tong Morton, Penn State University, presented a seminar in the Earth Science and Applications Division, September 11, 1990.

Dr. John Neuschaefer, Lafayette, Colorado, was retained to assist repair and calibration of the ascent wind profiler, January 28, through March 31, 1991.

Dr. James J. O'Brien, Tallahassee, Florida, was invited to provide a lecture to the NASA Earth Science and Applications Division, March 6-8, 1988.

Dr. Peter O'Rourke, Los Alamos Laboratories, was appointed to make an invited presentation at the workshop, "Mixing and Demixing Processes in Multiphase Flows with Applications to Propulsion Systems." The workshop was held at NASA/MSFC, February 25-26, 1988.

Dr. Natthu Parate, Prairie View A & M University, collaborated with Dr. Rebecca McCaleb and Dr. Jeff Anderson on regulatory and policy aspects of environment issues relevant for NASA operations. He presented a series of lectures on environmental sensitivity management for NASA from May 22, through July 31, 1991.

Dr. C. Russell Philbrick, Penn State University, participated in the NASP-GRAM workshop held at Marshall Space Flight Center, November 14-15, 1990.

Mr. Gregg Pratt, Boulder, Colorado, was appointed to assist with the Doppler Radar Wind Profiler Archival System, November 11, 1990.

Mr. Robert Raskin, Ann Arbor, Michigan, presented a seminar in the Earth Sciences and Applications Division, August 28-29, 1990.

Mr. Paul A. Robinson, University of Toronto, Institute for Aerospace Studies, was appointed to visit NASA/MSFC and provide a seminar relating to his work in aeronautical engineering, June 14-15, 1989.

Dr. Fredrick Sanders, Marblehead, Massachusetts, participated in the workshop on the Relationship of the Thunderstorm Storm Forecasting to Shuttle Flight Operations at Johnson Space Center, December 9-10, 1987.

Dr. William R. Savoie, Huntsville, Alabama, was appointed to design the multi-tasking application code to interface between the field mill sensors and the base station that aids Kennedy Space Center and the Air Force in determining the threat of lightning strikes to launch vehicles, April 1, through June 1, 1991.

Mr. Orvel Smith, Huntsville, Alabama, was appointed to collaborate with Dr. Bob Smith to review an unsolicited proposal entitled, "Atmospheric Winds for Aerospace Vehicle Design Applications," and develop a preliminary natural environment definitions document for the Natural Aerospace Plan (NASP), October 1988.

Dr. Robert E. Smith, Huntsville, Alabama, was appointed to assist with the revision of the criteria guidelines document entitled, "Atmospheric Winds for Aerospace Vehicle Application," September 1989. He also revised and updated the National Aerospace Plane (NASP) Natural Environment Data Book on orbital environments, May 2-11, 1990.

Dr. Patricia Snyder, Huntsville, Alabama, was appointed from September 1, 1990, through March 31, 1993, to accomplish the following tasks:

- a) Develop a diagnostic model and required inputs based on existing sets of measurements to analyze variability of middle atmosphere on the global scale;
- b). Advise NASA on the structure and accuracy of the database needed to diagnose state of the middle atmosphere based on the results of the first task;

- c) Construct preliminary computer code to synthesize measurements from various sensors with appropriately scaled version of the diagnostic model to describe the state of the middle atmosphere as a function of time.

Dr. William W. Vaughn, Huntsville, Alabama, was retained on an on-going basis to review and make specific recommendations regarding the development of natural environment design criteria and guidelines, mission operation analysis and design applications, content and scope of proposals and supporting documents, and assist in reviewing and making recommendations on earth science and application program content, scope and development.

Dr. Vaughn represented USRA and NASA at scientific meetings related to launch commit criteria and natural environments for NASA proposed spacecraft. His period of performance began August 18, 1987, and ended March 31, 1993.

Mr. James E. Weatherly, III, Huntsville, Alabama, performed data analyses, calculations, and library research in support of natural environment studies relevant to space and launch vehicles, January 9, through June 19, 1989.

Dr. Morris L. Weisman, Boulder, Colorado, participated in the workshop on the Relationship of Thunderstorm Forecasting to Shuttle Flight Operations at Johnson Space Center, December 9-10, 1987.

Dr. Jean-Marie Wersinger, Auburn University, conducted research on magnetospheric plasma physics at the Space Science Lab at MSFC, August 7-11, 1989.

Mr. Clint Wolff, Boulder, Colorado, was appointed to assist in the repair and calibrate the ascent wind profiler, March 11-31, 1991.

Dr. Ed Zipser, NCAR, Boulder, Colorado, presented a series of lectures under USRA's "Distinguished Visitor/Seminar Series," January 18-20, 1988.

6. Subcontracts

USRA subcontracted to The BDM Corporation, to provide research on a project entitled, "Monte Carlo Turbulence Simulation for Shuttle Re-entry Studies." The subcontract was effective December 23, 1987, through May 31, 1988.

Dr. C. G. Justus of Georgia Tech was issued a subcontracted to perform research entitled, "Tubulence Simulation Model for Space Shuttle Re-entry Applications." The subcontract was effective January 1, 1988, through July 1, 1988.

USRA subcontracted with Science and Applications International Corporation (SAIC) to provide research entitled, "Proposed Radiation Assessments for Space Station." The subcontract was effective July 1, 1988, through November 30, 1989.

Combustions and Explosives Research, Inc., A Division of Energy Systems Associates (ESA), in Pittsburgh, Pennsylvania, was issued a subcontract to provide research and prepare a report entitled, "Model Testing Using Marshall Space Flight Center Turbine Blade Test Facility to Find Requirements for Excess Hydrogen Disposal at KSC Launch Complex 39 SSME Shutdown." The research was completed September 1991.

7. Financial

Total Contract Value:	\$1,114,763
Total Cumulative Costs:	\$1,107,307
Estimated Residual Funds:	\$ 7,456

The period of performance was extended to March 31, 1993, from March 31, 1991, at no additional cost to the government to complete NASA reporting requirements. Remaining dollars are due to revisions in indirect rates and will be adjusted upon completion of the final contract audit.



Report Documentation Page

1. Report No.		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Natural Environment Service Support to NASA Vehicle, Technology and Sensor Development Program.				5. Report Date April 30, 1993	
				6. Performing Organization Code	
7. Author(s) Paula P. Cushman Contracts/Office Manager				8. Performing Organization Report No.	
				10. Work Unit No.	
9. Performing Organization Name and Address Universities Space Research Association 4950 Corporate Drive, Suite 100 Huntsville, Alabama 35806				11. Contract or Grant No. NAS8-36639	
				13. Type of Report and Period Covered Final Report 7/7/87-3/31/93	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546-0001 and George C. Marshall Space Flight Center NASA/MSFC, Alabama 35824				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract Contract NAS8-36639, a project to define the environmental parameters affecting launch vehicles. Research conducted toward this objective through USRA's Visiting Scientist Program. Research tasks included: defining national environmental parameters critical for design, development and operation of launch vehicles, defining environmental forecasts required to assure optimal utilization of launch vehicles, define orbital environments of operation and develop models on environmental parameters affecting launch vehicle operations. For more specific details regarding program activities, please contact Dr. Michael W. Kalb, Program Director, (205) 895-0582 or Mr. Kelly Hill, COR, (205) 544-1664.					
17. Key Words (Suggested by Author(s))				18. Distribution Statement	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of pages 10	
				22. Price	